Extinction

is forever

J.C. Daniel

Series Editor, Bittu Sahgal

NCSTC-HORNBILL
NATURAL HISTORY SERIES

Jointly published by:

Vigyan Prasar,
C-24, Institutional Area, ASCI Building,
Behind Qutab Hotel, New Delhi-110 016
email: <vigyan@hub.nic.in>

&

Sanctuary Magazine,
602, Maker Chambers V,
Nariman Point, Mumbai-400021.
email: <bittu@giasbm01.vsnl.net.in>

ISBN 81-7480-022-0
NCSTC-HORNBILL Natural History Series
Printed in Mumbai, India by Selprint

Extinction

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This account of the passage of life forms has been penned by one of India's most respected earth scientists. Tracing the map of extinctions from the dawn of life to recent times, the author, *J.C. Daniel,* Honorary Secretary of the Bombay Natural History Society, records for posterity the manner in which the ape that walks is altering the very foundations of life on earth.

"Mass extinction exhibits a cyclic nature, occurring approximately every 26 or 28 million years during the last 250 million years of earth history," suggests the author, even as he cautions us on the consequences of hastening the pace at which nature intended life forms to fade away.

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NCSTC-HORNBILL
NATURAL HISTORY SERIES

Exclusive Distributers:
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e-mail: ubspd.del@smy.sprintrpg.ems.vsnl.net.in
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(not to scale)

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Editor's Note

The Bombay Natural History Society (BNHS) has been a fount of knowledge for over a century. It has created and nurtured thousands of naturalists from all walks of life. Today the Society continues to add to the body of information gathered by all-time greats such as R.W. Burton, E.P. Gee, J.B. S. Haldane and, of course, Dr. Salim Ali, the 'Grand Old Man of Ornithology.' Long before the subject of environment had become fashionable; before the word biodiversity had even been coined, the study of nature was a mission for hundreds of BNHS members. In time this enduring institution gave birth to an amazing network of amateur naturalists. Their prime joy, apart from tramping India's wilds, has always been to share their experiences, knowledge and information about nature with others.

It is in this context that the production of the NCSTC-HORNBILL series should be viewed. India is losing its natural wealth at a frightening pace and it is vital that decision-makers are exposed to the very real value of the ecological assets being lost to the nation. It is equally important that the rationale for wildlife conservation is understood. Humans, for instance, do not possess the technology to re-create the millions of hectares of natural forests, grasslands and wetlands we lose each year.

To maintain and to enhance the green mantle, which protects our soil and our water sources, we need the elephant to transport mango seeds. We also need chital to carry grasses from one part of the forest to the other as we do the tiny leaf warbler's non-toxic 'pest control' contribution. The cleaning service performed by turtles and crocodiles, frogs and the larvae of dragonflies helps make the water in our lakes and rivers drinkable. Every creature on Planet Earth performs a useful ecological role... save for *Homo sapiens.*

We probably started out right, but our capacity for abstract thought, our intellect and our relatively recent penchant for

consumerism, have lulled us into the mistaken belief that we can escape the consequences of the grievous damage we inflict on ecosystems and species. With each forest we lose, each river we degrade, each mangrove and coastline ecosystem we alter, the viability of the Indian subcontinent to sustain future Indians is diminished. Simultaneously the quality of life of perhaps over 100 million earth-people: among them, fisherfolk, forest dwellers, nomads and pastoralists... is lowered and their security compromised.

This latter aspect of the environmental and wildlife movements has only just begun to assert itself in our national psyche. Young people everywhere, social activists and human rights groups are fast recognising that protecting forests for the tiger, rhino and elephant automatically serves to protect both forest cultures and resources for communities which live outside the market system.

In the coming days this new partnership between naturalists and earth-people is destined to play a vital role in defending wild India. If theNCSTC-Hornbill Natural History Series manages to enhance the ecological information base of decision makers and to replace pure sentimentalism with pragmatism in the battle to save nature... our purpose will have been admirably served.

The attention of readers is drawn to the annexure printed on page 37 which is a faithful reproduction of Chapter 14 of that classic work, *The Origin of Species* by Charles Darwin. There can be few better ways to fully comprehend the issue of extinction, so graphically, portrayed by *J.C. Daniel*, than to delve into the mind of the man who altered our conception of life on earth itself.

Bittu Sahgal, Editor
NCSTC-Hornbill Natural History Series

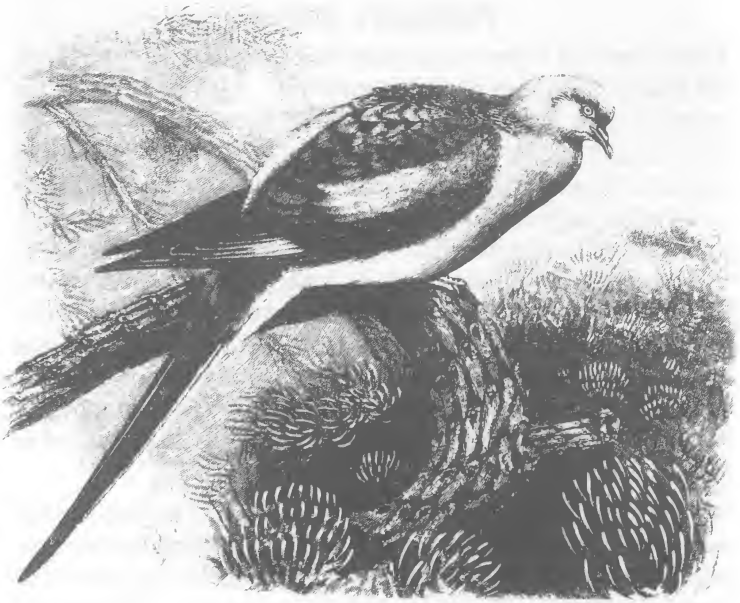
Publisher's Preface

This is one of a series of booklets that have been in the making for years! The wait has been worth it... both in terms of the contents and the fact that we have been able to win the involvement of the most authoritative authors on the various subjects chosen for the titles in the National Council for Science and Technology Communication, *NCSTC-HORNBILL Natural History Series.* NCSTC and the Bombay Natural History Society (BNHS) joined hands to bring the science of natural history to young people though adults too are sure to relate to the style and straightforward presentation. We intend to produce more titles each year to cover as wide a spectrum of nature as possible. We expect the publications to serve the dual purpose of disseminating information and keeping an archival record on the eve of the next millenium.

We wish to demystify the subject of ecology... to make it both understandable and acceptable to India's future decision-makers. The inter-relationships, the complex webs of existence, the contentious and confusing environmental issues... all these will need to be understood and grappled with by tomorrow's citizens. To the extent possible, we have stayed away from scientific jargon for obvious reasons. We did not wish this initiative to be reduced to an isolated 'lesson' of the kind one often sees being taught in our schools and colleges.

In this book, J.C. Daniel, one of India's most respected naturalists, shows readers just how and why extinction has always been a part and parcel of nature's way. But, he points out, we are pushing extinction along at a pace with which the system cannot cope. We must slow down, he suggests. We trust that this (and the other titles in the series) will encourage readers to search for the larger picture, the totality of inter-relationships... and thus better understand our own role on this planet.

Dr. Narender Sehgal, Series Publisher,
Director Vigyan Prasar, June 5, 1997



Extinction is for ever – the Passenger Pigeon

Second only to the Dodo in terms of its dubious fame, the Passenger Pigeon, Ectopistes migratorius, *is a classic example of animal extermination. Some 2,000 million birds were once believed to have flown American skies. James Audubon, the famous illustrator confirmed seing a column of Passenger Pigeons filling the sky so that the "light of the noon day sun was obscured as by an eclipse." That we could actually cause such a species to go extinct seems unthinkable, but that is exactly what we did. These were the famous 'stool pigeons' of folk lore. In Michigan reports talk of one single hunt in 1878 when an estimated 1,000 million birds were destroyed at nesting sites. By 1896 there were no more than 250,000 birds left alive. On September 1, 1914 the last Passenger Pigeon, named Martha, died in captivity in the Cincinnati Zoo.*

Extinction, as the word is commonly used and understood, means 'dying out'. In our desperate efforts to save an endangered species or conserve scarce natural resources, we often tend to forget that extinction is a well-established process in evolution. In fact, evolution and extinction go hand in hand. The approximately 9,000 living species of birds that exist today, are the descendants of lineages that began to diverge from one another about 150 million years ago in the late Jurassic (170 million years ago) and early Cretaceous (140 million years ago) period of earth history. 150,000 species of birds are estimated to have lived since then, and the species still alive are a mere six per cent of this total. The rest are extinct. It should, therefore, be very evident that though life itself is apparently everlasting, its manifestations, whether in the form of a dinosaur or a mouse, are only transient – a phase in the process of evolution. I say 'apparently everlasting' deliberately, as the natural course of extinction has now become alarmingly distorted by human interference in natural processes. Changes that took place over millions of years have now been compressed into periods of less than a few hundreds of years. The extinction of life on earth is now a distinct possibility. An enormous number of species have come into existence since life first appeared on the planet, over 600 million years ago. Species have evolved, prospered, and disappeared as the environmental conditions that permitted their existence changed. But this process of extinction is not all encompassing. There are several obscure species, not as spectacular as the dinosaur or the sabre-toothed tiger, which have let time and the changing world pass by with little change in their gross anatomy or their habits.

"Apparently ever-lasting, the extinction of life on earth is now seen as a distinct possibility"

Living fossils

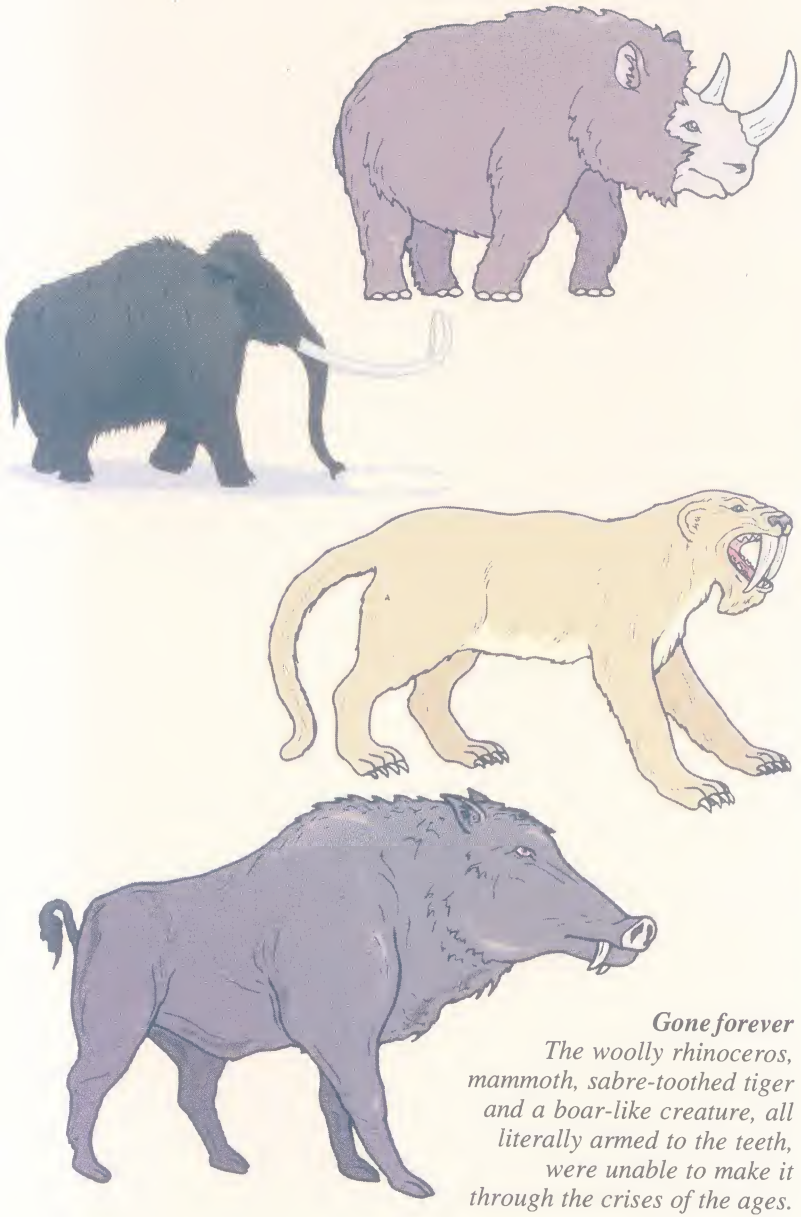
The Peripatus is a classic example of such a species that has come to us more or less unchanged from the hoary past. A lowly, terrestrial arthropod which looks like a caterpillar, with nearly twenty pairs of short, unjointed legs ending in hook-like claws, the Peripatus has a head equipped with a pair of pointed antennae and a pair of strong jaws. Breathing is carried out by means of the trachea just as in insects. There are about sixty species widely but disjunctly distributed in the moist forests of the West Indies, Central and South America, South Africa, Australia, New Zealand and Malaysia.

The Peripatus is extremely specialised in its habitat requirements. As a result it is isolated to environmental islands where the main criterion is humidity. The animals are unable to withstand dryness, and desiccation. Their survival in the face of the changes that the world has undergone is an enigma that is not easily solved. There is an absence of that all-important mixing of genes for arid zones in between isolated populations and hinder the evolution of new types. This fragile species has existed almost unchanged from the Silurian period of earth's history 350 million years ago, when terrestrial life first appeared on earth. Their fossils, particularly of a marine form *Ayshesia* from the Cambrian era (520 million years ago) indicate that the Peripatus has undergone little change over this vast period of time. Such animals that have survived beyond their era are termed 'living fossils'.

"Our country too, is home to one such 'living fossil' – the king crab."

Our country too, is home to one such 'living fossil' – the king crab. The king crab or more correctly the horse shoe crab, (for in appearance, it does look like a horseshoe fitted with a spike-

Survivors all
Thanks to special adaptations – camouflage for the boa, poisonous secretions for the frog and flaps that enabled the 'flying' lizard to glide, these creatures are among those that managed to survive the trauma of harsh environments through the ages.



Gone forever
The woolly rhinoceros, mammoth, sabre-toothed tiger and a boar-like creature, all literally armed to the teeth, were unable to make it through the crises of the ages.

like tail) has persisted over 300 million years. Five species of this group placed in three different genera have come down to us, relatively unchanged from the time they first appeared on earth. This group also has the distinction of being one of the first animals to be recorded in a scientific book, the *Historia Animalium* by Joannes Jonstonius, published in 1558. One species, *Tachypleus gigas* of this extraordinarily long-living group, occurs along the eastern seacoast of West Bengal and Orissa. The other species, as is the pattern among living fossils, are disjunctly distributed along the eastern coast of North America, South Japan, Malaysia, Moluccas in Indonesia and from North Borneo to the seas of China.

"The Peripatus and horse shoe crab are exceptions to the 'extinction rule'."

That these groups survived is less of an enigma than the survival of the Peripatus. They do not require particularly special environmental conditions, having lived for these millions of centuries in the shallow coastal waters of the seas where they forage in the sand or mud for worms and molluscs. The female migrates from offshore waters to bury her two to three hundred eggs deep in the sands of the intertidal zone. The young larvae that resemble their ancestors of the Cambrian era of 500 million years ago assume adult appearance in a month. This uncomplicated system of life has permitted the horse shoe crab to somehow survive for 300 million years. Nemesis is, however, at hand. Man, the great destroyer, has been over-exploiting them wherever they occur and these obscure, unobtrusive life forms are well on the way to extinction.

The Peripatus and horse shoe crab are exceptions to the rule that for all the animals that have lived on our earth there comes a period when time stops and they disappear. The process of

extinction is not the result of a single factor, but that of multiple factors set off perhaps by a single dominant cause. There have been several cycles of extinction in the history of the earth. The main cause for concern now is that we have already reached the last cycle of extinction.

Mass extinctions

As I mentioned earlier, the earth has been in existence for the past four billion years. In this long period of its history, life has been in existence for approximately the last 600 million years. Of course, it may have been in existence prior to this time, but animals with skeletons capable of leaving fossilised remains as a record of their presence in the world first appear in the rocks of the earth at a period 600 million years ago. Palaeontology, or the study of fossils, has discovered that since this period, life on the planet has progressed unsteadily, punctuated by cycles of mass extinctions, when entire sets of life forms have abruptly disappeared. The term 'abruptly' should not be misinterpreted to mean that these life-forms were there one day and disappeared the next. In fact they disappeared finally over a period of time which may extend for a few million years, which in terms of earth's time scale would be equivalent to a fraction of a second. These major revolutionary changes in the type of life that inhabited the earth at a given time have been termed as mass extinctions. There is now evidence that these mass extinctions were possibly triggered off or were given the final thrust into oblivion by the impact of extra-terrestrial objects. A mass extinction involves a simultaneous extinction of such unrelated groups as, for example, bottom-dwelling clams and surface-dwelling plankton or land-dwelling dinosaurs and oceanic mosa-

"Extinctions were probably triggered by impact with extraterrestrial objects."

saur reptiles. Accelerated extinction among many unrelated groups at a particular point of time is evidence that something extraordinary had taken place. Using this benchmark five mass extinctions in earth history have been identified and in-depth studies are likely to uncover evidence of another dozen. Fossil records show that mass extinctions occurred in the Ordovician era (450 million years ago), late Devonian (350 million years ago), late Permian (275 million years ago), late Triassic (190 million years ago) and late Cretaceous (65 million years ago). These extinctions show up in the fossil records as sudden, unexplained drops in the number of families recorded. Among these the late Permian extinction shows evidence of being the most devastating, with over 52 per cent of the then existing families becoming extinct. This means that almost 91 per cent to 96 per cent of the existing species were lost and life itself was almost wiped out. The extinction that has attracted the greatest attention and evoked the most interest in the late Cretaceous was the spectacular disappearance of the dinosaurs, the gigantic reptiles.

"Extinction was most severe in the tropics where entire reef colonies died."

The Alvarez Hypothesis

Several unsubstantiated and often absurd explanations have been put forward by the scientific community and popular science writers explaining the disappearance of the dinosaur. The main fault of these hypotheses is that they cannot explain the disappearance of the other animal groups that disappeared at the same time as the dinosaurs. A hypothesis, which has presently risen to prominence is the Alvarez Hypothesis, which states that the impact of an extra-terrestrial object triggered off the late Cretaceous mass extinction. This impact hypothesis has

the advantage that it can be tested. The Alvarez Hypothesis is based on the discovery of iridium in an earth layer, at the level of the late Cretaceous extinction. Why should the occurrence of iridium at this particular layer on the earth's crust be of special interest? It is owing to the fact that the earth's original supply of iridium sank to its core four billion years ago as the earth cooled. Therefore, any high enrichment of iridium in an earth layer of what is normally a trace element could be taken as the residue of the core of a comet or other extra-terrestrial bodies that had collided with the earth. The impact hypothesis could be tested with the prediction that the iridium-rich clay layer should be present exactly at the same level where there is a sedimentary record of that particular period. This has been proved as all localities that have been checked in various countries and in the sea have the expected iridium layer at just the right earth age level.

"We should be warned: once a species is driven to the edge it is lost forever."

Another condition was that other by-products of the collision such as osminum, chromium and cobalt should be expected and these have also been observed and recorded. An additional piece of evidence is the occurrence of tiny globules similar to microtectites, which result from the stress of high impact on sand grains having quartz. The impact hypothesis is therefore considered plausible enough to be treated seriously.

What would be the effect of such a collision? It has been postulated that depending on the size of the extra-terrestrial object colliding with the earth, the impact could produce so much dust that the earth would not receive sunlight for anything from two months to a year. This would be time sufficient enough to stop photosynthesis, thus bringing the production of food on earth to

a standstill. Temperatures would drop all over the world to below freezing point for six months to two years. The shock of the impact would create a host of chemical reactions resulting in a rain of hot nitric acid, producing a greenhouse effect from the water vapour thrown up into the atmosphere. And if the collision were to take place in an ocean, it would produce enormous tsunami waves, 300 to 400 metres in height that would have swamped all low-lying areas, drowning most of the vegetation.

"The Alvarez Hypothesis is based on the discovery of iridium in an earth layer."

The problem with this approach is that it looks at the sequence of events in relation to only the victims and not the survivors. It seems unlikely that a disaster of such magnitude would permit life itself to survive. In fact, the enigma is that animals like the Peripatus and the horseshoe crab have come unscathed through this catastrophe as have the crocodiles, ancestral mammals and other life forms. It is probably safer to assume that the impact did change the climatic conditions, which in turn had far-reaching effects rather than just snuffing out all existing life.

Life on earth modified itself to keep in tune with the new conditions prevailing on the planet as a result of the impact. Flexibility was the key in this changed world. Those animals that were too rigidly specialised or lacked the key factors necessary for survival fell by the wayside as the ages wore on.

Mass extinctions were most severe in the tropics, destroying entire reef communities, which took millions of years to replace, usually by an entirely different type of reef building community. For example, the nudist clams were the dominant reef builders

at the end of the Cretaceous era and there was a 10 million-year gap before the present coral community took over.

The cyclic nature of extinctions

Various factors seem to have tantalising interlinks with mass extinctions. Glaciation and the retreat of the sea destroyed exceptional habitats on land and sea, causing drastic climatic changes. These are all hypotheses being considered as probable causes. Mass extinction exhibits a cyclic nature, occurring approximately every 26 or 28 million years during the last 250 million years of earth history.

"The Dodo, a flightless bird found in Mauritius, was one of man's first victims"

Astronomers now provide another hypothesis. There is a cloud of comets that surround the solar system. If any force disturbs the cloud, some of the comets are displaced into the solar system. This hypothesis seems to be supported by the age of the craters on the surface of the earth known from the past 250 million years of earth history. They number thirteen and date back 28 million years, which is indeed very close to the mass extinction dates. It has been concluded that when the sea level drops the accompanying environmental and climatic changes make life on earth especially vulnerable. The additional stress of the impact of extraterrestrial objects could then trigger mass extinction. A consideration of survival factors suggests that mass extinctions change the rules of survival. Species with widespread lineages have the best chances of survival. Mass extinction indicates that the history of life on earth has not progressed steadily. Instead, they break the hold of a particular group and make way for another that had the right characteristics to survive the holocaust of the mass extinction.

The dinosaurs and the mammals started together, and for 260 million years dinosaurs ruled the world with an exuberance of species occupying all available niches, while the mammals scurried around in the bush. The mass extinction of the dinosaurs in the late Cretaceous era saw mammals beginning to diversify and in the next 15 million years, they had occupied all the niches vacated by the dinosaurs. Mass extinctions were thus major triggers in the evolutionary turnovers.

Fossil records of mass extinction are an exemplary warning to man, a reminder that once a species or a network of species is driven to the edge, it is gone forever. In fact at the present rate, where extinction exceeds the rate of evolution of new species, we are on the verge of a man-made mass extinction particularly in the fragile tropics, the earth's most vulnerable region and the richest in bio-diversity.

"By the 20th century the huge herds of American bison were wiped out."

Extinction cannot be viewed in isolation from survival. As we have noted earlier, through every holocaust life slips through to flourish abundantly till the next cycle of disaster falls on the planet. Survival from immediate disasters is possible for families, which are widely distributed, and those that make the least demand on their environment and boast of a high degree of adaptability. It is from these obscure generalised and widely distributed families that life climbs back again into a new opportunity that opens up with the destruction of the old.

The question that needs serious consideration is whether man is creating conditions that could lead to the next cycle of mass extinction. To find an answer to this question one has to trace the progress of life from the Tertiary (75 million years ago) age

of mammals to the last million years - the Pleistocene and the most recent period the Holocene (10,000 years ago).

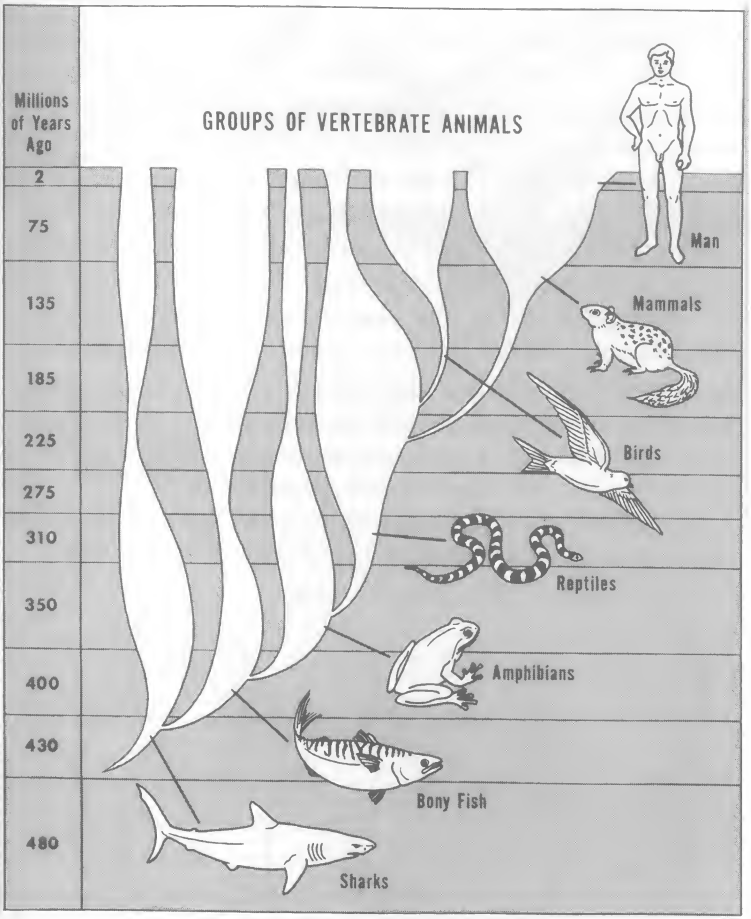
Gigantism and the relics of abundance

During this period mammals flourished both in number and variety of species. We are presently concerned with the relics of this abundance, the elephants, rhinoceroses, camels and horses which thrived in the age of mammals, not only in the number of species but also in the size of individual species. The Baluchitherium for instance was a gigantic rhinoceros, which stood around six metres tall and roamed the plains of Baluchistan, the Upnor elephant was about a quarter larger than the existing African elephant. Curiously enough, the tendency towards gigantism heralded a decline in the life of the group as a whole and was a prelude to extinction. The relict species are the remnants of a once dominant and established group of species. We shall discuss their present and future status later in this booklet.

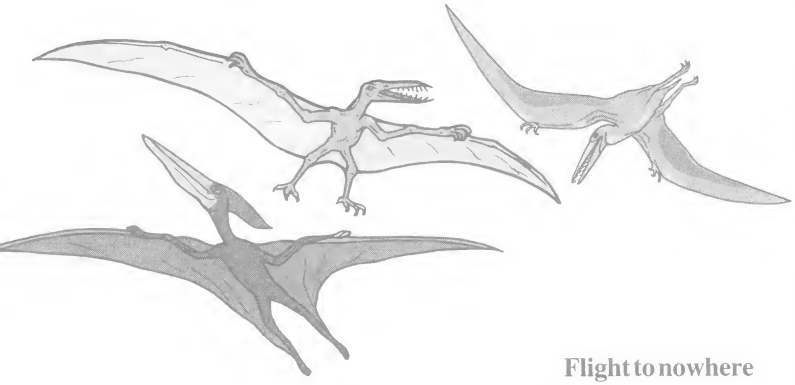
"The main reason for extinction of wildlife in India is habitat loss."

Many species like the Mastodon elephants and the American camel *Camelops hesternus*, which was of the same size as the present-day camel, coexisted with early man in America. But their disappearance can hardly be attributed to man. Man became a serious causative factor of extinction only during the last 500 years of earth history. This started with the period when the 'civilised' man of West Europe took to the seas, circumnavigated the globe and colonised continents which were till then still in their primeval setting, with the natural forces acting as the only arbitrators of life's progress and extinction.

Even here, man was not the main cause but only gave the last

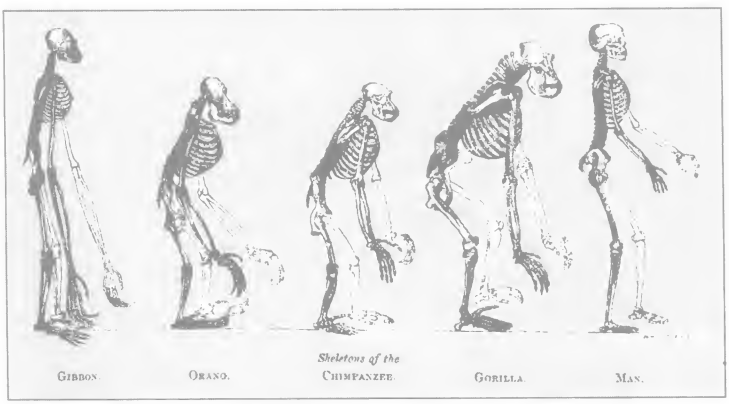


As can be judged by this evolutionary chart of vertebrates, through every holocaust life slips through to flourish abundantly till the next cycle of disaster falls on the planet. Survival from immediate disasters is possible for families, which are widely distributed, and those that make the least demand on their environment and boast of a high degree of adaptability. Given this fact, is Homo sapiens *soon likely to become the most endangered animal on the planet?*



Flight to nowhere

Having mastered the art of flight, pterodactyls (top) , winged reptiles that appeared in the late Jurassic, frequented seashore. They probably hung from perches in the manner of modern-day bats. Ramphorhynchus (beak-snouted) (middle) evolved towards the end of the Triassic and died out at the end of the Cretaceous. Pteranodon (wings, no-teeth) was the largest flying reptile ever with a wingspan of over eight metres.



Homo sapiens *belongs to an order of animals called 'primates' which share common characteristics such as grasping fingers and forward-pointed eyes. Over 70 million years, primate evolution has been characterised, among other things, by an increase in body size.*

thrust towards extinction either directly or indirectly. Some classic, well-documented examples can be cited. The story of the passenger pigeon is an illustrative example. A brightly-coloured pigeon of North America, it was present in great numbers when the Europeans first settled in North America, but the last of its race died in the Cincinnati Zoo, USA in 1914. In 1672, it was recorded that a flight of these pigeons was so extensive that it blocked out the sunlight. Audubon, the famous naturalist and bird painter estimated a flock that had at least a billion birds, which took over three hours to pass overhead. In 1866, a flock estimated to be 300 miles long and one mile wide obscured the sun for 14 hours, while in transit. These densely packed flocks were slaughtered with guns and even cannons. They were netted and clubbed to death to feed the innumerable human settlements, which were springing up all over the country. Even more disastrous to the bird was the cutting down of its nesting trees.

"Only in the last 500 years has man begun to be the cause of extinctions."

This uninhibited slaughter reached a stage when, in 1878, 300 tons of the birds were killed in a few weeks. By 1895, commercial killing was no longer viable. In the short period of 50 years the species had been reduced from abundance to extinction. This tragic story of the waste of national wealth is a pointer to the causes behind extinction. True, the slaughter was the critical cause for the mass extinction but there were several other contributory factors.

The destruction of the immense forests of Eastern America that provided food and nesting facilities was one. Other factors included the passenger pigeon's low breeding rate (each pair produced just one egg) and their rigid breeding behaviour (both

birds in a pair shared incubation, relieving each other with clock like regularity).

In living memory

The causes of extinction are seldom single. A predator (even as adept as man) cannot exterminate an entire species. If that were possible we would have, for example, no rats or for that matter, no rabbits in Australia. There are exceptions like the dodo: but there again, there was a multiplicity of causes; predation at different levels in the life of the species. The dodo, a large, flightless relative of the pigeon, found only in the Island of Mauritius was one of the first victims of the predatory European man in his sailing ships. The sailors found the defenceless, ground-dwelling adults excellent to eat. Moreover, the pests man introduced into the island: cats, dogs, pigs and rats ate both the eggs and young ones and as a result a highly specialised species restricted to a single island was snuffed out within a few years. In the nineteenth century, the quantum jump in the progress of man by what has been loosely termed as the Industrial Revolution probably only encouraged the extinction of species, which were already on the decline. The species were already threatened by a host of various other factors: man only administering the final push over the edge, as it were.

"For the pygmy hog, Manas' thatch -lands are a habitat without which it may go extinct."

A number of species that were on the decline became extinct by the turn of the century and the first few decades of the 20th century. The heath hen of North America became extinct by 1931. The flightless great auk, of the high northern altitudes, counterpart of the penguins of the Antarctic, was slaughtered to extinction by 1844. Steller's sea cow – a relative of the dugong found in the cold waters off the Behring Island – was killed off

by 1768. The common factor for the extinction of these species was the introduction of a new predator amidst a declining population already under heavy environmental stress. Other species which became extinct within recent times are the quagga, Burchels zebra and the tarpan (among the horses), the auroch or wild cattle of Europe, and among the birds the dodo of Mauritius and the moas of New Zealand. In all these extinctions, the heavy hand of man, though a key factor, was not the only factor.

"The wetlands of Kaziranga are crucial habitats for the survival of the wild buffalo."

By the turn of the twentieth century, the huge herds of the American bison, which roamed the plains of Midwest America, had been almost wiped out. Except for the African Continent, the balance was heavily tilted towards extinction. This was the time when guidelines should have been established for the wise use of natural resources. The opportunity was lost, in fact not even considered and the chance to stem the drift towards final extinction was lost. The African Continent, which resembled an earlier unsullied era of the Holocene, has since been despoiled.

Let us now look at the history of the species that have become extinct in our country within historic times and consider the status of species which are likely to become extinct within the 21st century.

Earlier, I had mentioned the relict species to be survivors of once widely distributed and flourishing life forms notable for the abundance and variety of their species. The camel is an example. In times gone by they occurred in a variety of species in the Americas, presently only the Llama and similar animals in South America and the two species of camels, the Bactrian and the

Arabian (both now known only as domesticated animals), occur. The five existing species of rhinoceros and the two species of elephants, the African and the Asian are other examples of relict survivors. How far away from extinction are these and other relicts is a point worth considering.

In 1959, Lee Talbot of the International Union for the Conservation of Nature & Natural Resources (IUCN) did a rapid survey of species both endangered and on the road to extinction. In his report *A Look at Threatened Species* he listed three species of mammals from the Indian subcontinent, the hangul or Kashmir stag *Cervus elaphus hanglu*, the onehorned Indian rhinoceros *Rhinoceros unicornis* and the Indian lion *Panthera leo persica*. Slightly over a decade later, the Indian Wild Life (Protection) Act, 1972 was enacted, and 50 per cent of all the mammal genera existing in India were on Schedule I of the Act. This listed completely protected species, included rare or little-known ones, and those endangered or likely to become extinct, or suspected of having become extinct. Presently the Act lists 29 species of mammals, birds and reptiles as rare or little known; one species of bird and one of mammals as extinct during this century and 24 species of mammals, birds, and reptiles as endangered and on the road to extinction. Each of these species is in this present precarious situation due to a variety of causes. The main reason for extinction of wildlife in India however is habitat destruction by a continually increasing human population and wasteful use of natural resources. Some case histories would be illustrative. Two species became extinct in India in the 20th century: the Pink-headed Duck was last seen in the wild in 1935 and the cheetah in 1949.

"In 1959 Lee Talbot said that the hangul, rhino and lion were on the road to extinction."

I have said earlier, is a cumulative process. In the
k-headed Duck the population was already at a low
iddle of the 19th century which is when it came to
f the scientific community. It was a species largely
he tall *terai* grasslands. The conversion of the
ultivation may have been one of the reasons for the
: of this resident ground nesting species. The
t other wild ducks have is that the majority are
., breeding elsewhere in the world. All but one of
eeding ducks nest in trees and secure the advantage
hat all tree nesting birds have.

k

st
d

The only other ground nesting duck, the Spotbill Duck *Anas poecilorhynda* is widely distributed and breeds in a variety of situations where chances of survival are bright. The Pink-headed Duck was thus a victim of specialised habitat and the loss of such habitats restricted distribution, predation by uninhibited hunting for sport. The ory runs parallel to that of the Pink-headed Duck. itant of open savannah forests and grasslands, the bitats to cultivation made sightings of the cheetah n the 19th century.

ehangir is said to have had a thousand cheetahs in ablishment. It is questionable that all these were ı, as a substantial number could have been imported ontinent with which India had a flourishing trade. e factors were loss of habitat and consequent loss ey species; a specialised hunting technique; low ıction potential (cheetahs rarely bred in captivity) ıting for sport providing the *coup de grace*.

No home on the range

Habitat destruction is the main cause of extinction in India. The continuous increase in human population and the escalating demand on our natural resources will add to the list of species on the road to extinction. A typical example of the loss of a specialised habitat is that of the riverine forest, swamp and grassland of eastern India. This region is severely in jeopardy and holds an extraordinarily large percentage of endangered mammals. It used to extend all along the foot of the Himalaya and along the course of the rivers that emerge from the Himalaya. On account of its suitability for the cultivation of crops people steadily displaced wildlife from this region.

"The Javan and Sumatran rhinos were also once found in India."

The loss can best be judged from the present and past distribution of the rhinoceros, an indicator species for the habitat. In historic times, the rhinoceros was distributed in the Indo-Gangetic Plain up to Peshawar in the west of Pakistan, where it was hunted by the Emperor Babar 400 years ago. Five endangered species are typical of this habitat; rhinoceros, swamp deer, wild buffalo, pygmy hog, and the hispid hare. One species of bird, the Pink-headed Duck, which favoured this habitat, is now extinct.

All three species of rhinoceros – the Javan, the Sumatran and the Great Indian once occurred in India. The Javan and the Sumatran became extinct in India by the turn of the century. The Indian rhinoceros was saved not only on account of the protection it received from the early years of this century, but also due to the fact that its habitat was earlier unsuitable for colonisation due to the prevalence of deadly diseases, such as malaria. The use of pesticides on a massive scale opened its habitat to intense human colonisation. The prevention of the extinction of this

While the cheetah is alive and well in Africa, it has been extinct in India since 1949. In fact, it is only one of two species known to have become extinct in India in the 20th century, the other being the Pink-headed Duck that was last seen in the wild in 1935. In India the cheetah was used for royal hunts and it was so abundant that 'stables' of over a thousand animals were reputed to have been maintained. But abundance is no security for any species, once its ecological foundation is eroded, or it is singled out for punishment by humans.

The zebra is one of Africa's most readily recognised mammals. So long as its grassland habitat is safe it will probably evade extinction. A relative, the quagga, was not quite so lucky. Isolated to a few habitats, in the earstwhile Cape Colony veldt and the Orange Free State, the quagga was hunted to extinction by the Boers. The last wild quagga was killed in 1878.

ancient animal must be considered a temporary success.

Vanishing wildernesses

Two sanctuaries of crucial importance in the protection of this habitat and its species from extinction: the Kaziranga and the Manas Sanctuaries in Assam. The Kaziranga holds the single largest population of the Indian rhinoceros, said to be over 1,000 in number but, presently considerably reduced by persistent poaching. The wild buffalo whose requirements closely parallel those of the rhinoceros and with which it lives in Kaziranga and Manas has a rather alarming genetic problem: dilution of the pure wild strain by domestic stock. A large number of domesticated buffalo, most of them genetically a 'cocktail species' bred by man, are grazed in the major wild buffalo habitats in Kaziranga and Manas. While this does revitalise the domestic strain, it has the opposite effect on the wild strain as can be seen from the deterioration of the horn structure and body features. It has become essential to prevent interbreeding with domestic stock, if the wild strain is to be saved from extinction.

"Domestic buffaloes are genetic 'cocktails'... wild stocks need to be protected."

The grassland habitat's most gravely endangered species, well on the road to extinction, is the diminutive pygmy hog, 25 cm at the shoulder and eight kgs. in weight for an adult male. Thought to be extinct, but rediscovered in the grass jungles of the *terai* in Assam, the population of the pygmy hog is scattered and occurs in small pockets of habitats that are largely in danger of being taken over for cultivation. The Bornadi Forest Reserve near the Assam – Bhutan international border, where most of the specimens have been obtained, has a total area of 24.6 sq. kms. of which eight sq. kms. have been extensively encroached. About half the sanctuary

is under the thatch grass species *Saccharum spontaneum* and *Phragmites karka*. These are burnt annually, restricting the pygmy hog to small unburned patches, thus increasing the chances of predation. Thirty to forty pygmy hogs are believed to occur in this area but for how long they will survive is an open question. For the pygmy hog, Manas with 40 sq. kms. of thatch land is the single most important habitat if the species is to be saved from extinction. Unfortunately, Manas itself is threatened with extinction by political unrest.

Another species almost on the verge of extinction is another grassland inhabitant – the lesser florican. Recent studies have highlighted the fact that the species is unlikely to survive this century. The lesser florican is seen only during the monsoon, its habits and habitat at other times of the year remaining shrouded in mystery. The species arrives in the grasslands of Western Madhya Pradesh and Saurashtra in Gujarat with the first regular showers of the monsoon. The males establish territories and begin their fantastic breeding display, a jack-in-the box type of jumping movements. A male may exhibit this kind of behaviour up to 400 times a day during peak breeding season. Once the season is over the birds disappear. It is still not known where they come from and where they go. Year by year, the breeding habitat is shrinking and the number of displaying males has also simultaneously decreased. The whole breeding cycle is so closely interlinked with the availability of suitable grasslands and arrival dates of the monsoon that the entire survival system of the species has become fragile. The absolute lack of data on post-monsoon distribution of the lesser florican makes the whole question of survival of the species beyond this century unlikely. This is an

"The gaur and the tiger cannot live with man, and may become extinct."

extinction that seems very difficult, even impossible, to prevent as it is backed by a multiplicity of causes, many of which are not even determined. Habitat loss, selective killing of breeding males in the course of display, close linkage with the now erratic monsoon rains, the lack of comprehensive information on the species makes it difficult to develop protective measures. Several other Indian species are so threatened as to be teetering on the brink of extinction.

All in one basket

These are the species with a single surviving population, namely the Kashmir stag or hangul *Cervus elaphus hanglu*, the sangai or brow-antlered deer *Cervus eldi eldi*, the peninsular race of the swamp deer and the Indian lion. The hangul is a race of the red deer and represents the extreme southern thrust in the enormous range of this widespread species. Confined now to the Kashmir Valley, the hangul was once widely distributed in the mountains of Kashmir with its population declining drastically since independence. It is of late further restricted to the 143 sq. kms. Dachigam Sanctuary near Srinagar. It summers in alpine meadows at 3,000 m. and in winter moves 15 kms. down into the valley of the Dagwan river. The hangul's summer range pastures are shared with domestic livestock. Also, as in wildlife areas elsewhere in India, illegal woodcutting remains a main source of continuous disturbance.

"Political instability threatens the survival of the hangul deer of Kashmir."

The Dachigam Sanctuary and the status of the hangul are further seriously threatened on account of political unrest and neither seems likely to survive this rauma. The brow-antlered deer too

is unlikely to survive in the wild. It occurs only in the Kaibul Lamjao Sanctuary in Manipur,—a low-lying swamp south of the huge Loktak lake. Originally, 20 sq. kms. of this was declared a sanctuary but it was later reduced to an area of ten sq. kms. The present area is 13.75 sq. kms. with the deer being confined to six sq. kms. The peculiar feature of this sanctuary is the islands of floating vegetation known as Phumdi which are formed of matted grass and reeds on which the deer lives.

The favoured food of the deer is *Saccharum latifolium* which forms five per cent of the grass composition of the islands and which is also the favoured food of the domestic buffalo that graze in the area. Moreover, these buffalo tend to trample on and compress the islands of matted vegetation, causing them to be grounded, further endangering the deer's habitat.

"The Manipur brow-antlered deer is gravely threatened and may become extinct."

The Manipur brow-antlered deer is also gravely endangered and in the present politically disturbed situation it will be a miracle if it survives in the wild. Another species with a single population is the peninsular race of the swamp deer, often referred to as the hard ground barasingha.

The swamp deer has survived because the Kanha meadow (or the Banjar Valley as it was known) has been a sanctuary since 1935. Over 3,000 such deer were counted in 1938 and the population fell to as low as 70 to 80 animals in 1971 before vigorous efforts were made to save the species. It was fortunate that Kanha, where the single population of this deer occurs was selected as a Project Tiger area. At present therefore, there is no danger of immediate extinction of the deer, as the main causes for decline, namely

habitat destruction and poaching appear to have been controlled.

End of the road for the Asiatic lion?

The Gir forest which houses the remnant population of the Asiatic lion, once abundant and widely distributed, can itself be considered a relict as there are no other similar forested areas in Saurashtra. The lion's existence in Gir is to some extent a parallel to that of the Maldhari herdsman of the same forest. In fact, the Indian lion has survived because it has been and continues to be non-violent towards man. If its behaviour towards man had been similar to that of the African lion, it would have been extinct by now.

"The web of life is being torn... the crux of the problem is the human way of life..."

The major hazard for the lion, as for other species threatened with extinction in India, is habitat loss. Gir once had an area of 2,590 sq. kms. and is presently reduced to 1,300 sq. kms. On the other hand, the lion has not only survived but also increased from about 14 animals at the turn of the century to over 250 now. The spectre of extinction however, still hangs over the species because of habitat loss and the absence of alternate homes for excess populations. With the Gir forest fringe being continually whittled for one reason or another, the future looks bleak.

We have looked briefly at some of the species among the many threatened with extinction. If we look at the possibility of extinction of life forms presently existing in the world, the situation is very bleak indeed. Again, taking India as an example for the malaise that affects the world, we can identify the many factors that are threatening all life throughout the world.

Invisible losses

The examples I have given are of only the visible survivors. Every year the country loses an unknown number of species as forests and grasslands are destroyed and the web of life continues to lose its binding strands. The crux of India's problems is its human population and the amount we consume. Demands on natural resources for human needs and the needs of domestic livestock are so great that very little is left for any other forms of life. This effect is heavily felt by all.

A brief review of some basic environmental parameters and the stress they presently bear will help us to understand the problem. India, although having hardly one-fortieth of the world's land surface, supports more than one-half of the world's water buffalo and more than one-seventh of its cattle and goats. The effect of constantly increasing pressure from these domestic animals on the land (particularly grasslands and forests) has been disastrous. In India, land urgently in need of rehabilitation because of wind and water erosion, salinity and alkalinity, now exceeds an area of 100 x 106 ha. The Chambal valley, with 4 x 106 ha ruined by eroded ravines, is a classical example that can repeat itself elsewhere.

"India has one-fortieth of the earth's land and one-seventh of the earth's cattle."

Another continuing pressure on land resources is urbanisation. The urban Indian population is the fourth largest in the world and it will continue to grow while agriculture on impoverished land, fragmented by inheritance distributions among members of a family, fails to support the increasing rural population. At the same time, more agricultural land is taken up to meet the demands of urbanisation. Approximately 1.5 x 106 ha of arable land have been

lost in this manner since 1950. These losses are borne in the final assessment by the forest and grassland habitat of India's wildlife and non-human life forms.

The second most important factor is water conservation. In historic times, rainfall was stored in ponds and tanks and this water was apparently sufficient to meet the requirements of the human population. These storage reservoirs have neither been maintained nor have they increased in number while continuing to be stretched to meet the needs of an expanding population. India still uses only one-tenth of the rainfall that it receives. Floods wreak havoc each year, but India still lacks an effective policy of flood control and water conservation. Groundwater reserves, which were once 10 times as great as the annual rainfall, have been so over used that in many areas the water table has fallen far below economically retrievable levels. Aridity is now threatening many areas that were once fertile. Our lack of respect for water has serious consequences.

"By the turn of the century India's human population will cross the one billion mark."

The third major consideration is energy. Firewood remains the main source of energy for cooking in India and particularly in villages where it often is the only source. Urban India alone uses 20 x 106 tons. of firewood, worth over 5,000 million rupees, more than the sum spent on afforestation between the years 1950 and 1980. The effect of this endless demand on resources is evident considering the area under forest cover. Satellite data indicate that India is losing 1.3 x 106 ha of forest per year; more than eight times the figure given by the Forest Departments of the various states (Agarwal and Narain, 1985). The situation has not improved. On the contrary, it has deteriorated.

In spite of these grave constraints, India still has a variety of habitats, albeit considerably reduced, as forests, grasslands, marshes, rivers and lakes that support its wealth of life. What are the chances of their survival?

2001: A space constraint odyssey?

By the turn of the present century the human population of India will cross the one billion mark. It is predicted that it will take about five to ten centuries for the growth in human population to stabilise and then decline. The resources we had discussed earlier namely water, energy and food for sustaining life would be hard to come by. As far as we are aware, the search for new sources of water is already on. Everyday we read of the inability of people to live together. Tolerance and adequate living space go together. Behavioural changes such as intolerance are directly related to overcrowding and are symptomatic of inadequate availability of life support systems which will soon result in a demographic disaster leading us on the road to extinction.

How will all this affect our Protected Areas (PAs)? Studies in other parts of the world provide some answers. There are two schools of thought, the management conservationist and the wilderness conservationist. The former is the multiple-use, sustainable-use conservationist. The latter urges protection to maintain an area in its pristine nature. But here again the thinking is that a core area should be protected for its own merits to maintain the unknown medicinal plants and other advantages that this area may hold for man! David Ehrenfield, the renowned conservationist speaks of an area — the Hucheson Forest of Rutgers University, a pristine forest existing from pre-colonial times in New Jersey USA — where the last major fire was in 1777. It has remained a closely guarded forest. Yet it has been heavily colonised by exotics. He concludes that 'You can fence

Two that did not get away...

The Dodo, Raphus cucullatus, *lived on the island of Mauritius where for millions of years birds had virtually no enemies. When Arab and Portuguese traders arrived on the scene the bird was simply not equipped to understand the threat they posed and it was, therefore, quite literally, bludgeoned to extinction for the value of its meat and oil.*

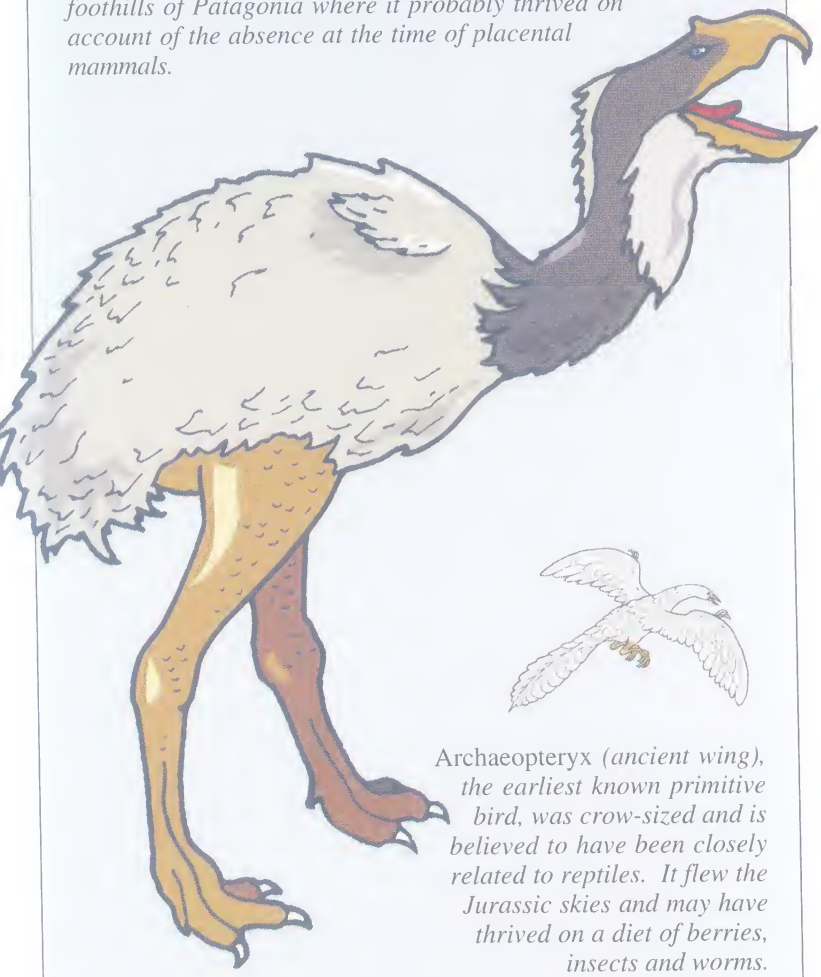
The Forest Spotted Owlet or Blewitt's Owl, Athene blewitti, *was found in and around the Satpura forests. It has not been seen since 1914 when the German collector (and friend of Dr. Salim Ali) shot it near Mandvi.*

... and one that did!

Jerdon's Doublebanded Courser, Rhinoptilus bitorquatus, *a sleek and beautiful bird was believed to be restricted to the Eastern Ghats of India. Reports from the 1860s suggest that it used to be seen "in small parties, not very noisy, but occcasionally uttering a plaintive cry". The last time anyone reported seeing the bird was in 1900. Subsequently many searches were organised, some by Dr. Salim Ali himself. However nothing turned up and the bird was presumed extinct... till a BNHS scientist, Bharat Bhushan, rediscovered the bird in Cudappah, Andhra Pradesh on January 14, 1986.*

The last confirmed sighting of the Pink-headed Duck was in Bihar, just before the turn of this century. It is now presumed extinct.

During the Tertiary some birds such as Phororhacos, *seen below, reached immense proportions. It stood over 3.5 metres tall and its head would have been larger than that of a modern-day horse! It preyed on reptiles and mammals and lived in the plains and foothills of Patagonia where it probably thrived on account of the absence at the time of placental mammals.*



Archaeopteryx *(ancient wing), the earliest known primitive bird, was crow-sized and is believed to have been closely related to reptiles. It flew the Jurassic skies and may have thrived on a diet of berries, insects and worms.*

out people but you cannot fence out their effects'. Studies have shown that protected areas that are actually oases in a sea of developmental activities lose species rapidly. It is estimated that by the time the world's primary tropical forests are lost i.e. by about the middle of the 21st century over half the 1.7 million species of plants and animals which have been named so far would have become extinct.

The larger mammals and birds would probably continue to exist in captivity. Even among these, the odds are that the social animals have a better chance of survival than the solitary living forms. It is a fact that domestic animals except the cat had progenitors that lived socially in herds or packs where submission of self to a group was essential. These were the ones that were domesticated and brought into the human social system. It is likely that the elephant, for instance, would probably be seen only as a domesticated animal in the 21st century. Animals such as the gaur and the tiger which are intolerant of human presence are likely to become extinct in the wild in the coming centuries.

The future is bleak. The past has shown us that the world changes. Even within man's short span on earth catastrophes have occurred. For example, the legend of an all-encompassing flood that left few survivors is a tradition of cultures in different parts of the world. There is no longer any place on this earth where the hand of man has not come down heavily. As regards the increase in human population, there is a clear divide between the industrialised nations of the North and the nations of the so-called Third World. The latter not only provide raw material to support a highly materialistic society in the developed countries but also ravage their own natural resources to support the needs of an unbridled population explosion which under existing social norms cannot be controlled. As the years go by there will be a

further sharp division between those regions of the world which have pauperized themselves for the abundant life support systems of other regions of the world. In this impoverishment lies the key to the road to extinction. In the next few centuries and the centuries to come the wild vegetation we will have will be the lantana, the *Prosopis* and the *Eupatorium*, the *Mikania.* Introduced exotics and wildlife will be the common pigeon, the crow, the feral pig, rats, the cat, the dog and insects, particularly forms such as the cockroach which have lived through several million centuries. True wildlife as we know, will perhaps be only in zoos.

Man himself, unless he can curb his needs, and develop a Gandhian, self-sufficient village community level existence will be swept into extinction by the contradictions and stresses of a never-ending materialistic society.

What would be the future, when the time comes for the next catastrophic cyclic change which seems likely with the probability of impact by a comet in the year 2126? Will man and other mammals win through or will the world see another experiment with another dominant life form? There is after all no doubt that life itself will manage to survive another catastrophe as it has done in the past.

Annexure

On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life.

Charles Darwin, M.A.

Chapter 14 - Recapitulation and Conclusion

- *Recapitulation of the difficulties on the theory of Natural Selection*
- *Recapitulation of the general and special circumstances in its favour*
- *Causes of the general belief in the immutability of species*
- *How far the theory of natural selection may be extended*
- *Effects of its adoption on the study of Natural history*
- *Concluding remarks*

As this whole volume is one long argument, it may be convenient to the reader to have the leading facts and inferences briefly recapitulated.

That many and grave objections may be advanced against the theory of descent with modification through natural selection, I do not deny. I have endeavoured to give to them their full force. Nothing at first can appear more difficult to believe than that the more complex organs and instincts should have been perfected not by means superior to, though analogous with, human reason, but by the accumulation of innumerable slight variations, each good for the individual possessor. Nevertheless, this difficulty, though appearing to our imagination insuperably great, cannot be considered real if we admit the following propositions, namely, — that gradations in the perfection of any organ or instinct, which we may consider, either do now exist or could have existed, each good of its kind, — that all organs and instincts are, in ever so slight a degree, variable, — and, lastly, that there is a struggle for existence leading to the preservation of each profitable deviation of structure or instinct. The truth of these propositions cannot, I think, be disputed. It is, no doubt, extremely difficult even to conjecture by what gradations many structures have been perfected, more especially amongst broken and failing groups of organic beings; but we see so many strange grada-

tions in nature, as is proclaimed by the canon, 'Natura non facit saltum,' that we ought to be extremely cautious in saying that any organ or instinct, or any whole being, could not have arrived at its present state by many graduated steps. There are, it must be admitted, cases of special difficulty on the theory of natural selection; and one of the most curious of these is the existence of two or three defined castes of workers or sterile females in the same community of ants but I have attempted to show how this difficulty can be mastered.

With respect to the almost universal sterility of species when first crossed, which forms so remarkable a contrast with the almost universal fertility of varieties when crossed, I must refer the reader to the recapitulation of the facts given at the end of the eighth chapter, which seem to me conclusively to show that this sterility is no more a special endowment than is the incapacity of two trees to be grafted together, but that it is incidental on constitutional differences in the reproductive systems of the intercrossed species. We see the truth of this conclusion in the vast difference in the result, when the same two species are crossed reciprocally; that is, when one species is first used as the father and then as the mother.

The fertility of varieties when intercrossed and of their mongrel offspring cannot be considered as universal; nor is their very general fertility surprising when we remember that it is not likely that either their constitutions or their reproductive systems should have been profoundly modified. Moreover, most of the varieties which have been experimentised on have been produced under domestication; and as domestication apparently tends to eliminate sterility, we ought not to expect it also to produce sterility.

The sterility of hybrids is a very different case from that of first crosses, for their reproductive organs are more or less functionally impotent; whereas in first crosses the organs on both sides are in a perfect condition. As we continually see that organisms of all kinds are rendered in some degree sterile from their constitutions having been disturbed by slightly different and new conditions of life, we need not feel surprise at hybrids being in some degree sterile, for their constitutions can hardly fail to have been disturbed from being compounded of two distinct organisations. This parallelism is supported by another parallel, but directly opposite, class of facts;

namely, that the vigour and fertility of all organic beings are increased by slight changes in their conditions of life, and that the offspring of slightly modified forms or varieties acquire from being crossed increased vigour and fertility. So that, on the one hand, considerable changes in the conditions of life and crosses between greatly modified forms, lessen fertility; and on the other hand, lesser changes in the conditions of life and crosses between less modified forms, increase fertility.

Turning to geographical distribution, the difficulties encountered on the theory of descent with modification are grave enough. All the individuals of the same species, and all the species of the same genus, or even higher group, must have descended from common parents; and therefore, in however distant and isolated parts of the world they are now found, they must in the course of successive generations have passed from some one part to the others. We are often wholly unable even to conjecture how this could have been effected. Yet, as we have reason to believe that some species have retained the same specific form for very long periods, enormously long as measured by years, too much stress ought not to be laid on the occasional wide diffusion of the same species; for during very long periods of time there will always be a good chance for wide migration by many means. A broken or interrupted range may often be accounted for by the extinction of the species in the intermediate regions. It cannot be denied that we are as yet very ignorant of the full extent of the various climatal and geographical changes which have affected the earth during modern periods; and such changes will obviously have greatly facilitated migration. As an example, I have attempted to show how potent has been the influence of the Glacial period on the distribution both of the same and of representative species throughout the world. We are as yet profoundly ignorant of the many occasional means of transport. With respect to distinct species of the same genus inhabiting very distant and isolated regions, as the process of modification has necessarily been slow, all the means of migration will have been possible during a very long period; and consequently the difficulty of the wide diffusion of species of the same genus is in some degree lessened.

As on the theory of natural selection an interminable number of

intermediate forms must have existed, linking together all the species in each group by gradations as fine as our present varieties, it may be asked, Why do we not see these linking forms all around us? Why are not all organic beings blended together in an inextricable chaos? With respect to existing forms, we should remember that we have no right to expect (excepting in rare cases) to discover directly connecting links between them, but only between each and some extinct and supplanted form. Even on a wide area, which has during a long period remained continuous, and of which the climate and other conditions of life change insensibly in going from a district occupied by one species into another district occupied by a closely allied species, we have no just right to expect often to find intermediate varieties in the intermediate zone. For we have reason to believe that only a few species are undergoing change at any one period; and all changes are slowly effected. I have also shown that the intermediate varieties which will at first probably exist in the intermediate zones, will be liable to be supplanted by the allied forms on either hand; and the latter, from existing in greater numbers, will generally be modified and improved at a quicker rate than the intermediate varieties, which exist in lesser numbers; so that the intermediate varieties will, in the long run, be supplanted and exterminated.

On this doctrine of the extermination of an infinitude of connecting links, between the living and extinct inhabitants of the world, and at each successive period between the extinct and still older species, why is not every geological formation charged with such links? Why does not every collection of fossil remains afford plain evidence of the gradation and mutation of the forms of life? We meet with no such evidence, and this is the most obvious and forcible of the many objections which may be urged against my theory. Why, again, do whole groups of allied species appear, though certainly they often falsely appear, to have come in suddenly on the several geological stages? Why do we not find great piles of strata beneath the Silurian system, stored with the remains of the progenitors of the Silurian groups of fossils? For certainly on my theory such strata must somewhere have been deposited at these ancient and utterly unknown epochs in the world's history.

I can answer these questions and grave objections only on the

supposition that the geological record is far more imperfect than most geologists believe. It cannot be objected that there has not been time sufficient for any amount of organic change; for the lapse of time has been so great as to be utterly inappreciable by the human intellect. The number of specimens in all our museums is absolutely as nothing compared with the countless generations of countless species which certainly have existed.

We should not be able to recognise a species as the parent of any one or more species if we were to examine them ever so closely, unless we likewise possessed many of the intermediate links between their past or parent and present states; and these many links we could hardly ever expect to discover, owing to the imperfection of the geological record. Numerous existing doubtful forms could be named which are probably varieties; but who will pretend that in future ages so many fossil links will be discovered, that naturalists will be able to decide, on the common view, whether or not these doubtful forms are varieties?

As long as most of the links between any two species are unknown, if any one link or intermediate variety be discovered, it will simply be classed as another and distinct species. Only a small portion of the world has been geologically explored. Only organic beings of certain classes can be preserved in a fossil condition, at least in any great number. Widely ranging species vary most, and varieties are often at first local, — both causes rendering the discovery of intermediate links less likely. Local varieties will not spread into other and distant regions until they are considerably modified and improved; and when they do spread, if discovered in a geological formation, they will appear as if suddenly created there, and will be simply classed as new species. Most formations have been intermittent in their accumulation; and their duration, I am inclined to believe, has been shorter than the average duration of specific forms. Successive formations are separated from each other by enormous blank intervals of time; for fossiliferous formations, thick enough to resist future degradation, can be accumulated only where much sediment is deposited on the subsiding bed of the sea. During the alternate periods of elevation and of stationary level the record will be blank. During these latter periods there will probably be more variability in the forms of life;

during periods of subsidence, more extinction.

With respect to the absence of fossiliferous formations beneath the lowest Silurian strata, I can only recur to the hypothesis given in the ninth chapter. That the geological record is imperfect all will admit; but that it is imperfect to the degree which I require, few will be inclined to admit. If we look to long enough intervals of time, geology plainly declares that all species have changed; and they have changed in the manner which my theory requires, for they have changed slowly and in a graduated manner. We clearly see this in the fossil remains from consecutive formations invariably being much more closely related to each other, than are the fossils from formations distant from each other in time.

Such is the sum of the several chief objections and difficulties which may justly be urged against my theory; and I have now briefly recapitulated the answers and explanations which can be given to them. I have felt these difficulties far too heavily during many years to doubt their weight. But it deserves especial notice that the more important objections relate to questions on which we are confessedly ignorant; nor do we know how ignorant we are. We do not know all the possible transitional gradations between the simplest and the most perfect organs; it cannot be pretended that we know all the varied means of Distribution during the long lapse of years, or that we know how imperfect the Geological Record is. Grave as these several difficulties are, in my judgement they do not overthrow the theory of descent with modification.

Now let us turn to the other side of the argument. Under domestication we see much variability. This seems to be mainly due to the reproductive system being eminently susceptible to changes in the conditions of life so that this system, when not rendered impotent, fails to reproduce offspring exactly like the parent-form. Variability is governed by many complex laws, — by correlation of growth, by use and disuse, and by the direct action of the physical conditions of life. There is much difficulty in ascertaining how much modification our domestic productions have undergone; but we may safely infer that the amount has been large, and that modifications can be inherited for long periods. As long as the conditions of life remain the same, we have reason to believe that a modification, which has

already been inherited for many generations, may continue to be inherited for an almost infinite number of generations. On the other hand we have evidence that variability, when it has once come into play, does not wholly cease; for new varieties are still occasionally produced by our most anciently domesticated productions.

Man does not actually produce variability; he only unintentionally exposes organic beings to new conditions of life, and then nature acts on the organisation, and causes variability. But man can and does select the variations given to him by nature, and thus accumulate them in any desired manner. He thus adapts animals and plants for his own benefit or pleasure. He may do this methodically, or he may do it unconsciously by preserving the individuals most useful to him at the time, without any thought of altering the breed. It is certain that he can largely influence the character of a breed by selecting, in each successive generation, individual differences so slight as to be quite inappreciable by an uneducated eye. This process of selection has been the great agency in the production of the most distinct and useful domestic breeds. That many of the breeds produced by man have to a large extent the character of natural species, is shown by the inextricable doubts whether very many of them are varieties or aboriginal species.

There is no obvious reason why the principles which have acted so efficiently under domestication should not have acted under nature. In the preservation of favoured individuals and races, during the constantly-recurrent Struggle for Existence, we see the most powerful and ever-acting means of selection. The struggle for existence inevitably follows from the high geometrical ratio of increase which is common to all organic beings. This high rate of increase is proved by calculation, by the effects of a succession of peculiar seasons, and by the results of naturalisation, as explained in the third chapter. More individuals are born than can possibly survive. A grain in the balance will determine which individual shall live and which shall die, – which variety or species shall increase in number, and which shall decrease, or finally become extinct. As the individuals of the same species come in all respects into the closest competition with each other, the struggle will generally be most severe between them; it will be almost equally severe between the varieties of the same

species, and next in severity between the species of the same genus. But the struggle will often be very severe between beings most remote in the scale of nature. The slightest advantage in one being, at any age or during any season, over those with which it comes into competition, or better adaptation in however slight a degree to the surrounding physical conditions, will turn the balance.

With animals having separated sexes there will in most cases be a struggle between the males for possession of the females. The most vigorous individuals, or those which have most successfully struggled with their conditions of life, will generally leave most progeny. But success will often depend on having special weapons or means of defence, or on the charms of the males; and the slightest advantage will lead to victory.

As geology plainly proclaims that each land has undergone great physical changes, we might have expected that organic beings would have varied under nature, in the same way as they generally have varied under the changed conditions of domestication. And if there be any variability under nature, it would be an unaccountable fact if natural selection had not come into play. It has often been asserted, but the assertion is quite incapable of proof, that the amount of variation under nature is a strictly limited quantity. Man, though acting on external characters alone and often capriciously, can produce within a short period a great result by adding up mere individual differences in his domestic productions; and every one admits that there are at least individual differences in species under nature. But, besides such differences, all naturalists have admitted the existence of varieties, which they think sufficiently distinct to be worthy of record in systematic works. No one can draw any clear distinction between individual differences and slight varieties; or between more plainly marked varieties and subspecies, and species. Let it be observed how naturalists differ in the rank which they assign to the many representative forms in Europe and North America.

If then we have under nature variability and a powerful agent always ready to act and select, why should we doubt that variations in any way useful to beings, under their excessively complex relations of life, would be preserved, accumulated, and inherited? Why, if man can by patience select variations most useful to himself, should nature fail

in selecting variations useful, under changing conditions of life, to her living products? What limit can be put to this power, acting during long ages and rigidly scrutinising the whole constitution, structure, and habits of each creature, — favouring the good and rejecting the bad? I can see no limit to this power, in slowly and beautifully adapting each form to the most complex relations of life. The theory of natural selection, even if we looked no further than this, seems to me to be in itself probable. I have already recapitulated, as fairly as I could, the opposed difficulties and objections: now let us turn to the special facts and arguments in favour of the theory.

On the view that species are only strongly marked and permanent varieties, and that each species first existed as a variety, we can see why it is that no line of demarcation can be drawn between species, commonly supposed to have been produced by special acts of creation, and varieties which are acknowledged to have been produced by secondary laws. On this same view we can understand how it is that in each region where many species of a genus have been produced, and where they now flourish, these same species should present many varieties; for where the manufactory of species has been active, we might expect, as a general rule, to find it still in action; and this is the case if varieties be incipient species. Moreover, the species of the large genera, which afford the greater number of varieties or incipient species, retain to a certain degree the character of varieties; for they differ from each other by a less amount of difference than do the species of smaller genera. The closely allied species also of the larger genera apparently have restricted ranges, and they are clustered in little groups round other species – in which respects they resemble varieties. These are strange relations on the view of each species having been independently created, but are intelligible if all species first existed as varieties.

As each species tends by its geometrical ratio of reproduction to increase inordinately in number; and as the modified descendants of each species will be enabled to increase by so much the more as they become more diversified in habits and structure, so as to be enabled to seize on many and widely different places in the economy of nature, there will be a constant tendency in natural selection to preserve the most divergent offspring of any one species. Hence

during a long-continued course of modification, the slight differences, characteristic of varieties of the same species, tend to be augmented into the greater differences characteristic of species of the same genus. New and improved varieties will inevitably supplant and exterminate the older, less improved and intermediate varieties; and thus species are rendered to a large extent defined and distinct objects. Dominant species belonging to the larger groups tend to give birth to new and dominant forms; so that each large group tends to become still larger, and at the same time more divergent in character. But as all groups cannot thus succeed in increasing in size, for the world would not hold them, the more dominant groups beat the less dominant. This tendency in the large groups to go on increasing in size and diverging in character, together with the almost inevitable contingency of much extinction, explains the arrangement of all the forms of life, in groups subordinate to groups, all within a few great classes, which we now see everywhere around us, and which has prevailed throughout all time. This grand fact of the grouping of all organic beings seems to me utterly inexplicable on the theory of creation.

As natural selection acts solely by accumulating slight, successive, favourable variations, it can produce no great or sudden modification; it can act only by very short and slow steps. Hence the canon of *'Natura non facit saltum,'* which every fresh addition to our knowledge tends to make more strictly correct, is on this theory simply intelligible. We can plainly see why nature is prodigal in variety, though niggard in innovation. But why this should be a law of nature if each species has been independently created, no man can explain.

Many other facts are, as it seems to me, explicable on this theory. How strange it is that a bird, under the form of woodpecker, should have been created to prey on insects on the ground; that upland geese, which never or rarely swim, should have been created with webbed feet; that a thrush should have been created to dive and feed on sub-aquatic insects; and that a petrel should have been created with habits and structure fitting it for the life of an auk or grebe! and so on in endless other cases. But on the view of each species constantly trying to increase in number, with natural selection always ready to adapt the slowly varying descendants of each to any unoccupied or ill-occupied

place in nature, these facts cease to be strange, or perhaps might even have been anticipated.

As natural selection acts by competition, it adapts the inhabitants of each country only in relation to the degree of perfection of their associates; so that we need feel no surprise at the inhabitants of any one country, although on the ordinary view supposed to have been specially created and adapted for that country, being beaten and supplanted by the naturalised productions from another land. Nor ought we to marvel if all the contrivances in nature be not, as far as we can judge, absolutely perfect; and if some of them be abhorrent to our ideas of fitness. We need not marvel at the sting of the bee causing the bee's own death; at drones being produced in such vast numbers for one single act, and being then slaughtered by their sterile sisters; at the astonishing waste of pollen by our fir-trees; at the instinctive hatred of the queen bee for her own fertile daughters; at ichneumonidae feeding within the live bodies of caterpillars; and at other such cases. The wonder indeed is, on the theory of natural selection, that more cases of the want of absolute perfection have not been observed.

The complex and little known laws governing variation are the same, as far as we can see, with the laws which have governed the production of so-called specific forms. In both cases physical conditions seem to have produced but little direct effect; yet when varieties enter any zone, they occasionally assume some of the characters of the species proper to that zone. In both varieties and species, use and disuse seem to have produced some effect; for it is difficult to resist this conclusion when we look, for instance, at the logger-headed duck, which has wings incapable of flight, in nearly the same condition as in the domestic duck; or when we look at the burrowing tucutucu, which is occasionally blind, and then at certain moles, which are habitually blind and have their eyes covered with skin; or when we look at the blind animals inhabiting the dark caves of America and Europe. In both varieties and species correction of growth seems to have played a most important part, so that when one part has been modified other parts are necessarily modified. In both varieties and species reversions to long-lost characters occur. How inexplicable on the theory of creation is the occasional appearance of stripes on the shoulder and legs of the several species of the horse-genus and in their hybrids! How simply is this fact

explained if we believe that these species have descended from a striped progenitor, in the same manner as the several domestic breeds of pigeon have descended from the blue and barred rock-pigeon!

On the ordinary view of each species having been independently created, why should the specific characters, or those by which the species of the same genus differ from each other, be more variable than the generic characters in which they all agree? Why, for instance, should the colour of a flower be more likely to vary in any one species of a genus, if the other species, supposed to have been created independently, have differently coloured flowers, than if all the species of the genus have the same coloured flowers? If species are only well-marked varieties, of which the characters have become in a high degree permanent, we can understand this fact; for they have already varied since they branched off from a common progenitor in certain characters, by which they have come to be specifically distinct from each other; and therefore these same characters would be more likely still to be variable than the generic characters which have been inherited without change for an enormous period. It is inexplicable on the theory of creation why a part developed in a very unusual manner in any one species of a genus, and therefore, as we may naturally infer, of great importance to the species, should be eminently liable to variation; but, on my view, this part has undergone, since the several species branched off from a common progenitor, an unusual amount of variability and modification, and therefore we might expect this part generally to be still variable. But a part may be developed in the most unusual manner, like the wing of a bat, and yet not be more variable than any other structure, if the part be common to many subordinate forms, that is, if it has been inherited for a very long period; for in this case it will have been rendered constant by long-continued natural selection.

Glancing at instincts, marvellous as some are, they offer no greater difficulty than does corporeal structure on the theory of the natural selection of successive, slight, but profitable modifications. We can thus understand why nature moves by graduated steps in endowing different animals of the same class with their several instincts. I have attempted to show how much light the principle of gradation throws on the admirable architectural powers of the hive-bee. Habit no doubt sometimes comes into play in modifying instincts; but it certainly is not

indispensable, as we see, in the case of neuter insects, which leave no progeny to inherit the effects of long-continued habit. On the view of all the species of the same genus having descended from a common parent, and having inherited much in common, we can understand how it is that allied species, when placed under considerably different conditions of life, yet should follow nearly the same instincts; why the thrush of South America, for instance, lines her nest with mud like our British species. On the view of instincts having been slowly acquired through natural selection we need not marvel at some instincts being apparently not perfect and liable to mistakes, and at many instincts causing other animals to suffer.

If species be only well-marked and permanent varieties, we can at once see why their crossed offspring should follow the same complex laws in their degrees and kinds of resemblance to their parents, — in being absorbed into each other by successive crosses, and in other such points, — as do the crossed offspring of acknowledged varieties. On the other hand, these would be strange facts if species have been independently created, and varieties have been produced by secondary laws.

If we admit that the geological record is imperfect in an extreme degree, then such facts as the record gives, support the theory of descent with modification. New species have come on the stage slowly and at successive intervals; and the amount of change, after equal intervals of time, is widely different in different groups. The extinction of species and of whole groups of species, which has played so conspicuous a part in the history of the organic world, almost inevitably follows on the principle of natural selection; for old forms will be supplanted by new and improved forms. Neither single species nor groups of species reappear when the chain of ordinary generation has once been broken. The gradual diffusion of dominant forms, with the slow modification of their descendants, causes the forms of life, after long intervals of time, to appear as if they had changed simultaneously throughout the world. The fact of the fossil remains of each formation being in some degree intermediate in character between the fossils in the formations above and below, is simply explained by their intermediate position in the chain of descent. The grand fact that all extinct organic beings belong to the

same system with recent beings, falling either into the same or into intermediate groups, follows from the living and the extinct being the offspring of common parents. As the groups which have descended from an ancient progenitor have generally diverged in character, the progenitor with its early descendants will often be intermediate in character in comparison with its later descendants; and thus we can see why the more ancient a fossil is, the oftener it stands in some degree intermediate between existing and allied groups. Recent forms are generally looked at as being, in some vague sense, higher than ancient and extinct forms; and they are in so far higher as the later and more improved forms have conquered the older and less improved organic beings in the struggle for life. Lastly, the law of the long endurance of allied forms on the same continent, of marsupials in Australia, of edentata in America, and other such cases, – is intelligible, for within a confined country, the recent and the extinct will naturally be allied by descent.

Looking to geographical distribution, if we admit that there has been during the long course of ages much migration from one part of the world to another, owing to former climatal and geographical changes and to the many occasional and unknown means of dispersal, then we can understand, on the theory of descent with modification, most of the great leading facts in Distribution. We can see why there should be so striking a parallelism in the distribution of organic beings throughout space, and in their geological succession throughout time; for in both cases the beings have been connected by the bond of ordinary generation, and the means of modification have been the same. We see the full meaning of the wonderful fact, which must have struck every traveller, namely, that on the same continent, under the most diverse conditions, under heat and cold, on mountain and lowland, on deserts and marshes, most of the inhabitants within each great class are plainly related; for they will generally be descendants of the same progenitors and early colonists. On this same principle of former migration, combined in most cases with modification, we can understand, by the aid of the Glacial period, the identity of some few plants, and the close alliance of many others, on the most distant mountains, under the most different climates; and likewise the close alliance of some of the inhabitants of the sea in the northern and

southern temperate zones, though separated by the whole intertropical ocean. Although two areas may present the same physical conditions of life, we need feel no surprise at their inhabitants being widely different, if they have been for a long period completely separated from each other; for as the relation of organism to organism is the most important of all relations, and as the two areas will have received colonists from some third source or from each other, at various periods and in different proportions, the course of modification in the two areas will inevitably be different.

On this view of migration, with subsequent modification, we can see why oceanic islands should be inhabited by few species, but of these, that many should be peculiar. We can clearly see why those animals which cannot cross wide spaces of ocean, as frogs and terrestrial mammals, should not inhabit oceanic islands; and why, on the other hand, new and peculiar species of bats, which can traverse the ocean, should so often be found on islands far distant from any continent. Such facts as the presence of peculiar species of bats, and the absence of all other mammals, on oceanic islands, are utterly inexplicable on the theory of independent acts of creation.

The existence of closely allied or representative species in any two areas, implies, on the theory of descent with modification, that the same parents formerly inhabited both areas; and we almost invariably find that wherever many closely allied species inhabit two areas, some identical species common to both still exist. Wherever many closely allied yet distinct species occur, many doubtful forms and varieties of the same species likewise occur. It is a rule of high generality that the inhabitants of each area are related to the inhabitants of the nearest source whence immigrants might have been derived. We see this in nearly all the plants and animals of the Galapagos archipelago, of Juan Fernandez, and of the other American islands being related in the most striking manner to the plants and animals of the neighbouring American mainland; and those of the Cape de Verde archipelago and other African islands to the African mainland. It must be admitted that these facts receive no explanation on the theory of creation.

The fact, as we have seen, that all past and present organic beings constitute one grand natural system, with group subordinate to group,

and with extinct groups often falling in between recent groups, is intelligible on the theory of natural selection with its contingencies of extinction and divergence of character. On these same principles we see how it is, that the mutual affinities of the species and genera within each class are so complex and circuitous. We see why certain characters are far more serviceable than others for classification; — why adaptive characters, though of paramount importance to the being, are of hardly any importance in classification; why characters derived from rudimentary parts, though of no service to the being, are often of high classificatory value; and why embryological characters are the most valuable of all. The real affinities of all organic beings are due to inheritance or community of descent. The natural system is a genealogical arrangement, in which we have to discover the lines of descent by the most permanent characters, however slight their vital importance may be.

The framework of bones being the same in the hand of a man, wing of a bat, fin of the porpoise, and leg of the horse, — the same number of vertebrae forming the neck of the giraffe and of the elephant, — and innumerable other such facts, at once explain themselves on the theory of descent with slow and slight successive modifications. The similarity of pattern in the wing and leg of a bat, though used for such different purposes, — in the jaws and legs of a crab, — in the petals, stamens, and pistils of a flower, is likewise intelligible on the view of the gradual modification of parts or organs, which were alike in the early progenitor of each class. On the principle of successive variations not always supervening at an early age, and being inherited at a corresponding not early period of life, we can clearly see why the embryos of mammals, birds, reptiles, and fishes should be so closely alike, and should be so unlike the adult forms. We may cease marvelling at the embryo of an air-breathing mammal or bird having branchial slits and arteries running in loops, like those in a fish which has to breathe the air dissolved in water, by the aid of well-developed branchiae.

Disuse, aided sometimes by natural selection, will often tend to reduce an organ, when it has become useless by changed habits or under changed conditions of life; and we can clearly understand on this view the meaning of rudimentary organs. But disuse and selec-

tion will generally act on each creature, when it has come to maturity and has to play its full part in the struggle for existence, and will thus have little power of acting on an organ during early life; hence the organ will not be much reduced or rendered rudimentary at this early age. The calf, for instance, has inherited teeth, which never cut through the gums of the upper jaw, from an early progenitor having well-developed teeth; and we may believe, that the teeth in the mature animal were reduced, during successive generations, by disuse or by the tongue and palate having been fitted by natural selection to browse without their aid; whereas in the calf, the teeth have been left untouched by selection or disuse, and on the principle of inheritance at corresponding ages have been inherited from a remote period to the present day. On the view of each organic being and each separate organ having been specially created, how utterly inexplicable it is that parts, like the teeth in the embryonic calf or like the shrivelled wings under the soldered wing-covers of some beetles, should thus so frequently bear the plain stamp of inutility! Nature may be said to have taken pains to reveal, by rudimentary organs and by homologous structures, her scheme of modification, which it seems that we wilfully will not understand.

I have now recapitulated the chief facts and considerations which have thoroughly convinced me that species have changed, and are still slowly changing by the preservation and accumulation of successive slight favourable variations. Why, it may be asked, have all the most eminent living naturalists and geologists rejected this view of the mutability of species? It cannot be asserted that organic beings in a state of nature are subject to no variation; it cannot be proved that the amount of variation in the course of long ages is a limited quantity; no clear distinction has been, or can be, drawn between species and well-marked varieties. It cannot be maintained that species when inter-crossed are invariably sterile, and varieties invariably fertile; or that sterility is a special endowment and sign of creation. The belief that species were immutable productions was almost unavoidable as long as the history of the world was thought to be of short duration; and now that we have acquired some idea of the lapse of time, we are too apt to assume, without proof, that the geological record is so perfect that it would have afforded us plain evidence of the mutation of species, if

they had undergone mutation.

But the chief cause of our natural unwillingness to admit that one species has given birth to other and distinct species, is that we are always slow in admitting any great change of which we do not see the intermediate steps. The difficulty is the same as that felt by so many geologists, when Lyell first insisted that long lines of inland cliffs had been formed, and great valleys excavated, by the slow action of the coast-waves. The mind cannot possibly grasp the full meaning of the term of a hundred million years; it cannot add up and perceive the full effects of many slight variations, accumulated during an almost infinite number of generations.

Although I am fully convinced of the truth of the views given in this volume under the form of an abstract, I by no means expect to convince experienced naturalists whose minds are stocked with a multitude of facts all viewed, during a long course of years, from a point of view directly opposite to mine. It is so easy to hide our ignorance under such expressions as the 'plan of creation,' 'unity of design,' &c., and to think that we give an explanation when we only restate a fact. Any one whose disposition leads him to attach more weight to unexplained difficulties than to the explanation of a certain number of facts will certainly reject my theory. A few naturalists, endowed with much flexibility of mind, and who have already begun to doubt on the immutability of species, may be influenced by this volume; but I look with confidence to the future, to young and rising naturalists, who will be able to view both sides of the question with impartiality. Whoever is led to believe that species are mutable will do good service by conscientiously expressing his conviction; for only thus can the load of prejudice by which this subject is overwhelmed be removed.

Several eminent naturalists have of late published their belief that a multitude of reputed species in each genus are not real species; but that other species are real, that is, have been independently created. This seems to me a strange conclusion to arrive at. They admit that a multitude of forms, which till lately they themselves thought were special creations, and which are still thus looked at by the majority of naturalists, and which consequently have every external characteristic feature of true species, – they admit that these have been produced by variation, but they refuse to extend the same view to other and very

slightly different forms. Nevertheless they do not pretend that they can define, or even conjecture, which are the created forms of life, and which are those produced by secondary laws. They admit variation as a vera causa in one case, they arbitrarily reject it in another, without assigning any distinction in the two cases. The day will come when this will be given as a curious illustration of the blindness of preconceived opinion. These authors seem no more startled at a miraculous act of creation than at an ordinary birth. But do they really believe that at innumerable periods in the earth's history certain elemental atoms have been commanded suddenly to flash into living tissues? Do they believe that at each supposed act of creation one individual or many were produced? Were all the infinitely numerous kinds of animals and plants created as eggs or seed, or as full grown? and in the case of mammals, were they created bearing the false marks of nourishment from the mother's womb? Although naturalists very properly demand a full explanation of every difficulty from those who believe in the mutability of species, on their own side they ignore the whole subject of the first appearance of species in what they consider reverent silence.

It may be asked how far I extend the doctrine of the modification of species. The question is difficult to answer, because the more distinct the forms are which we may consider, by so much the arguments fall away in force. But some arguments of the greatest weight extend very far. All the members of whole classes can be connected together by chains of affinities, and all can be classified on the same principle, in groups subordinate to groups. Fossil remains sometimes tend to fill up very wide intervals between existing orders. Organs in a rudimentary condition plainly show that an early progenitor had the organ in a fully developed state; and this in some instances necessarily implies an enormous amount of modification in the descendants.

Throughout whole classes various structures are formed on the same pattern, and at an embryonic age the species closely resemble each other. Therefore I cannot doubt that the theory of descent with modification embraces all the members of the same class. I believe that animals have descended from at most only four or five progenitors, and plants from an equal or lesser number.

Analogy would lead me one step further, namely, to the belief that all

animals and plants have descended from some one prototype. But analogy may be a deceitful guide. Nevertheless all living things have much in common, in their chemical composition, their germinal vesicles, their cellular structure, and their laws of growth and reproduction. We see this even in so trifling a circumstance as that the same poison often similarly affects plants and animals; or that the poison secreted by the gall-fly produces monstrous growths on the wild rose or oak-tree. Therefore I should infer from analogy that probably all the organic beings which have ever lived on this earth have descended from some one primordial form, into which life was first breathed.

When the views entertained in this volume on the origin of species, or when analogous views are generally admitted, we can dimly foresee that there will be a considerable revolution in natural history. Systematists will be able to pursue their labours as at present; but they will not be incessantly haunted by the shadowy doubt whether this or that form be in essence a species. This I feel sure, and I speak after experience, will be no slight relief. The endless disputes whether or not some fifty species of British brambles are true species will cease. Systematists will have only to decide (not that this will be easy) whether any form be sufficiently constant and distinct from other forms, to be capable of definition; and if definable, whether the differences be sufficiently important to deserve a specific name. This latter point will become a far more essential consideration than it is at present; for differences, however slight, between any two forms, if not blended by intermediate gradations, are looked at by most naturalists as sufficient to raise both forms to the rank of species. Hereafter we shall be compelled to acknowledge thatthe only distinction between species and well-marked varieties is, that the latter are known, or believed, to be connected at the present day by intermediate gradations, whereas species were formerly thus connected. Hence, without quite rejecting the consideration of the present existence of intermediate gradations between any two forms, we shall be led to weigh more carefully and to value higher the actual amount of difference between them. It is quite possible that forms now generally acknowledged to be merely varieties may hereafter be thought worthy of specific names, as with

the primrose and cowslip; and in this case scientific and common language will come into accordance. In short, we shall have to treat species in the same manner as those naturalists treat genera, who admit that genera are merely artificial combinations made for convenience. This may not be a cheering prospect; but we shall at least be freed from the vain search for the undiscovered and undiscoverable essence of the term species.

The other and more general departments of natural history will rise greatly in interest. The terms used by naturalists of affinity, relationship, community of type, paternity, morphology, adaptive characters, rudimentary and aborted organs, &c., will cease to be metaphorical, and will have a plain signification. When we no longer look at an organic being as a savage looks at a ship, as at something wholly beyond his comprehension; when we regard every production of nature as one which has had a history; when we contemplate every complex structure and instinct as the summing up of many contrivances, each useful to the possessor, nearly in the same way as when we look at any great mechanical invention as the summing up of the labour, the experience, the reason, and even the blunders of numerous workmen; when we thus view each organic being, how far more interesting, I speak from experience, will the study of natural history become!

A grand and almost untrodden field of inquiry will be opened, on the causes and laws of variation, on correlation of growth, on the effects of use and disuse, on the direct action of external conditions, and so forth. The study of domestic productions will rise immensely in value. A new variety raised by man will be a far more important and interesting subject for study than one more species added to the infinitude of already recorded species. Our classifications will come to be, as far as they can be so made, genealogies; and will then truly give what may be called the plan of creation. The rules for classifying will no doubt become simpler when we have a definite object in view. We possess no pedigrees or armorial bearings; and we have to discover and trace the many diverging lines of descent in our natural genealogies, by characters of any kind which have long been inherited. Rudimentary organs will speak infallibly with respect to the nature of long-lost structures. Species and groups of species, which are called aberrant,

and which may fancifully be called living fossils, will aid us in forming a picture of the ancient forms of life. Embryology will reveal to us the structure, in some degree obscured, of the prototypes of each great class.

When we can feel assured that all the individuals of the same species, and all the closely allied species of most genera, have within a not very remote period descended from one parent, and have migrated from some one birthplace; and when we better know the many means of migration, then, by the light which geology now throws, and will continue to throw, on former changes of climate and of the level of the land, we shall surely be enabled to trace in an admirable manner the former migrations of the inhabitants of the whole world. Even at present, by comparing the differences of the inhabitants of the sea on the opposite sides of a continent, and the nature of the various inhabitants of that continent in relation to their apparent means of immigration, some light can be thrown on ancient geography.

The noble science of Geology loses glory from the extreme imperfection of the record. The crust of the earth with its embedded remains must not be looked at as a well-filled museum, but as a poor collection made at hazard and at rare intervals. The accumulation of each great fossiliferous formation will be recognised as having depended on an unusual concurrence of circumstances, and the blank intervals between the successive stages as having been of vast duration. But we shall be able to gauge with some security the duration of these intervals by a comparison of the preceding and succeeding organic forms. We must be cautious in attempting to correlate as strictly contemporaneous two formations, which include few identical species, by the general succession of their forms of life. As species are produced and exterminated by slowly acting and still existing causes, and not by miraculous acts of creation and by catastrophes; and as the most important of all causes of organic change is one which is almost independent of altered and perhaps suddenly altered physical conditions, namely, the mutual relation of organism to organism, — the improvement of one being entailing the improvement or the extermination of others; it follows, that the amount of organic change in the fossils of consecutive formations probably serves as a fair measure of the lapse of actual time. A number of species, however, keeping in a body might remain for a long period

unchanged, whilst within this same period, several of these species, by migrating into new countries and coming into competition with foreign associates, might become modified; so that we must not overrate the accuracy of organic change as a measure of time. During early periods of the earth's history, when the forms of life were probably fewer and simpler, the rate of change was probably slower; and at the first dawn of life, when very few forms of the simplest structure existed, the rate of change may have been slow in an extreme degree. The whole history of the world, as at present known, although of a length quite incomprehensible by us, will hereafter be recognised as a mere fragment of time, compared with the ages which have elapsed since the first creature, the progenitor of innumerable extinct and living descendants, was created.

In the distant future I see open fields for far more important researches. Psychology will be based on a new foundation, that of the necessary acquirement of each mental power and capacity by gradation. Light will be thrown on the origin of man and his history.

Authors of the highest eminence seem to be fully satisfied with the view that each species has been independently created. To my mind it accords better with what we know of the laws impressed on matter by the Creator, that the production and extinction of the past and present inhabitants of the world should have been due to secondary causes, like those determining the birth and death of the individual. When I view all beings not as special creations, but as the lineal descendants of some few beings which lived long before the first bed of the Silurian system was deposited, they seem to me to become ennobled.

Judging from the past, we may safely infer that not one living species will transmit its unaltered likeness to a distant futurity. And of the species now living very few will transmit progeny of any kind to a far distant futurity; for the manner in which all organic beings are grouped, shows that the greater number of species of each genus, and all the species of many genera, have left no descendants, but have become utterly extinct. We can so far take a prophetic glance into futurity as to foretel that it will be the common and widely-spread species, belonging to the larger and dominant groups, which will ultimately prevail and procreate new and dominant species. As all the living forms

of life are the lineal descendants of those which lived long before the Silurian epoch, we may feel certain that the ordinary succession by generation has never once been broken, and that no cataclysm has desolated the whole world. Hence we may look with some confidence to a secure future of equally inappreciable length. And as natural selection works solely by and for the good of each being, all corporeal and mental endowments will tend to progress towards perfection.

It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being Growth with Reproduction; inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the external conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less-improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.